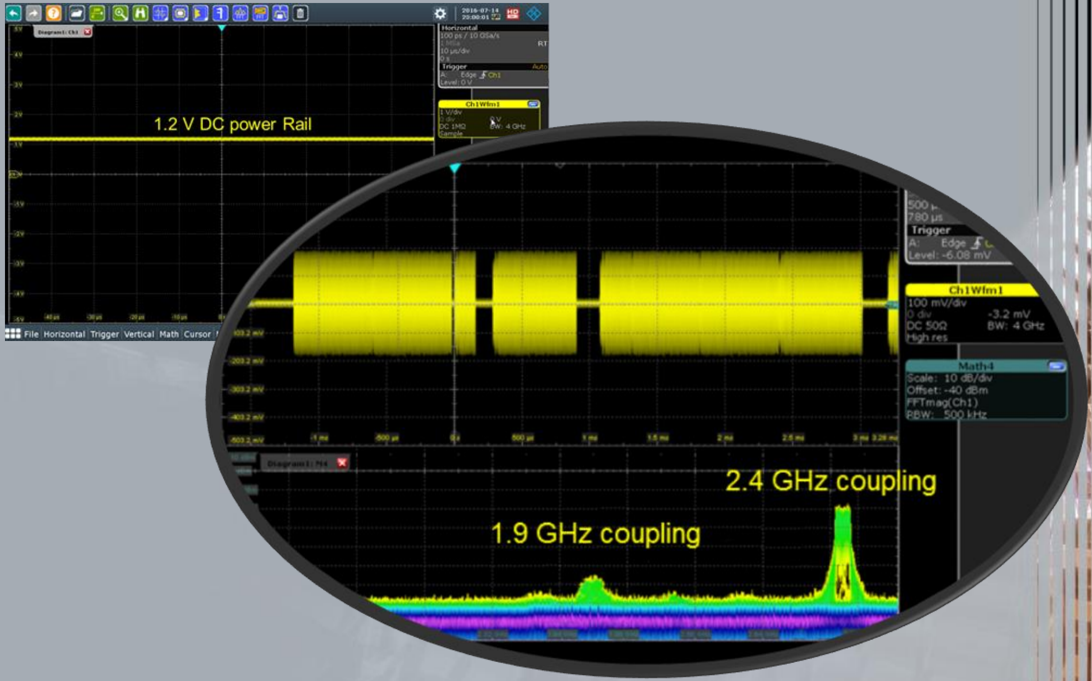
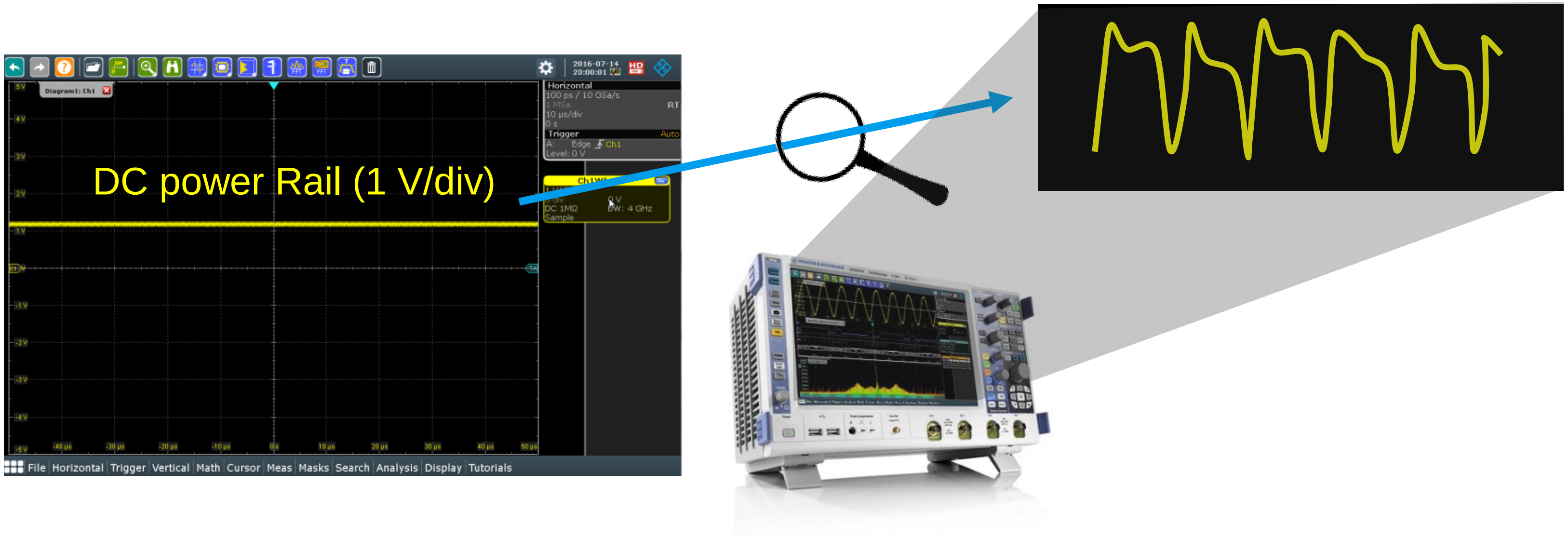
Techniques for Accurate Power Integrity Measurements, Faster with Your Oscilloscope



Rohde and Schwarz

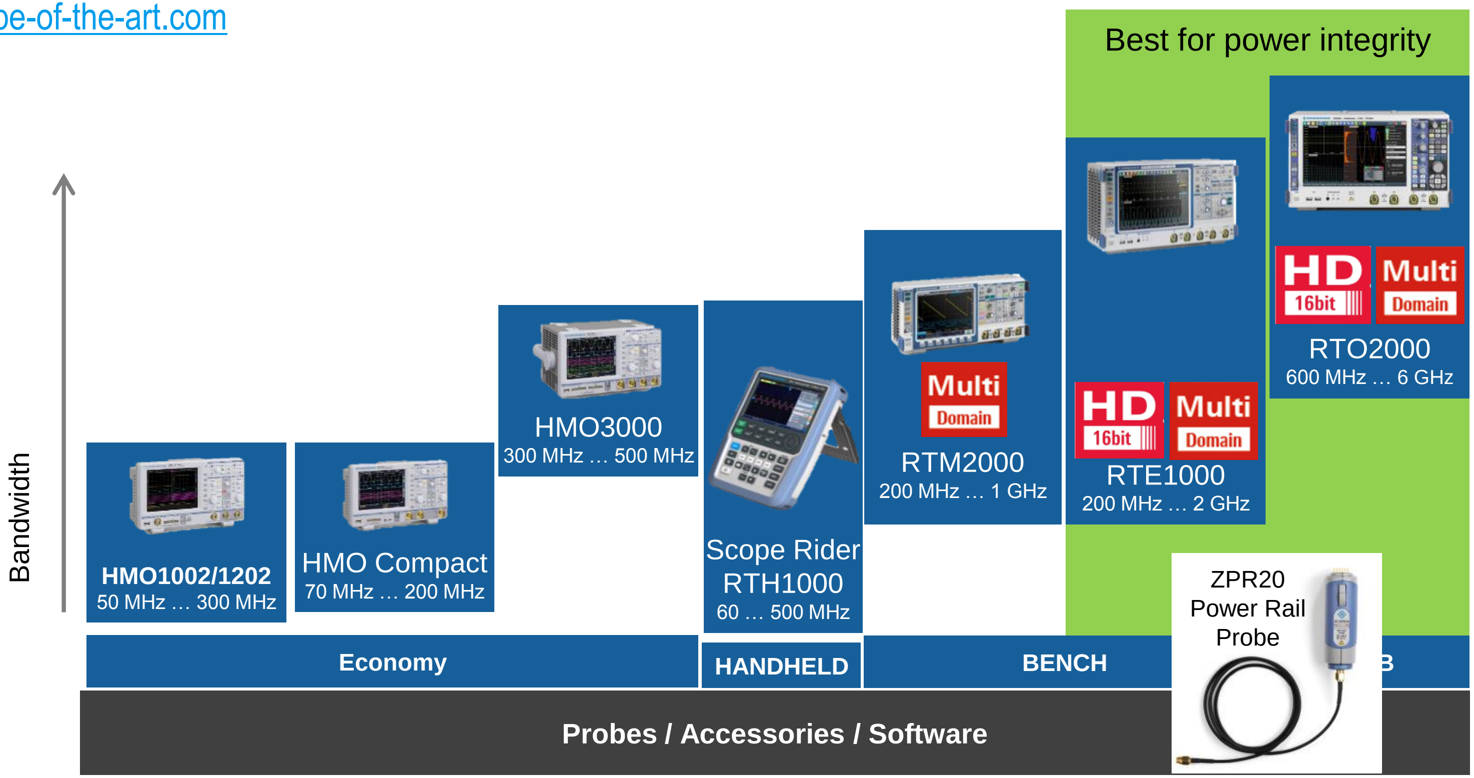
ROHDE&SCHWARZ

Oscilloscopes: Primary Tool for Power Rail Analysis



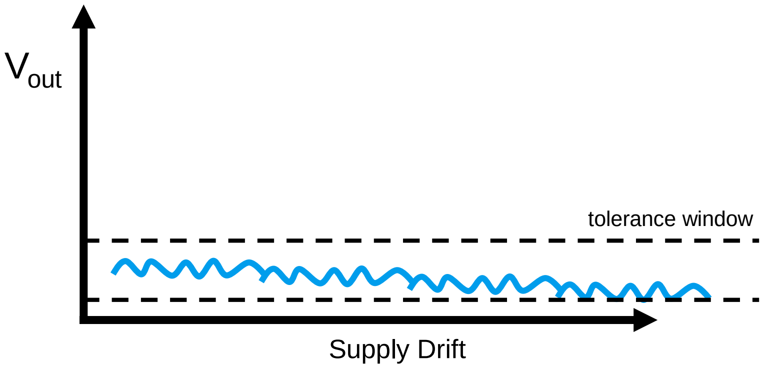
Rohde & Schwarz Oscilloscope Portfolio

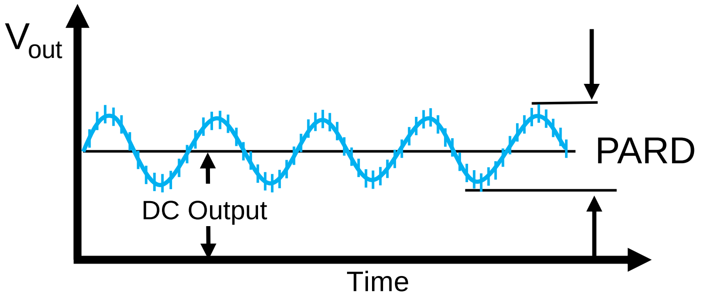
www.scope-of-the-art.com



Common Power Integrity Measurements

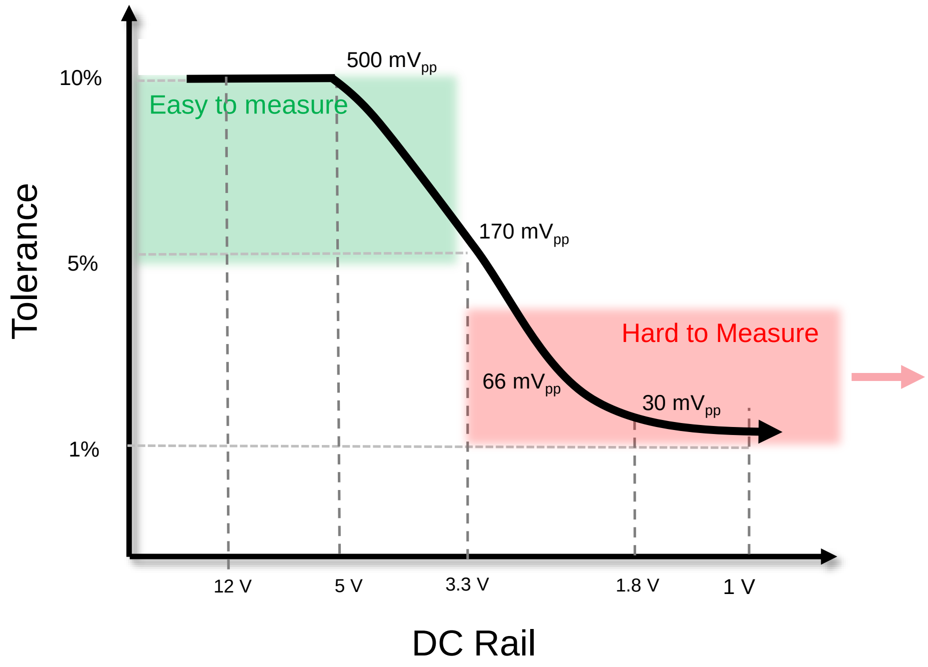
- PARD (Periodic and Random Disturbances): noise, ripple (V_{pp}), transients
- Static and dynamic load response
- Supply drift





Power Rail Measurement Challenges

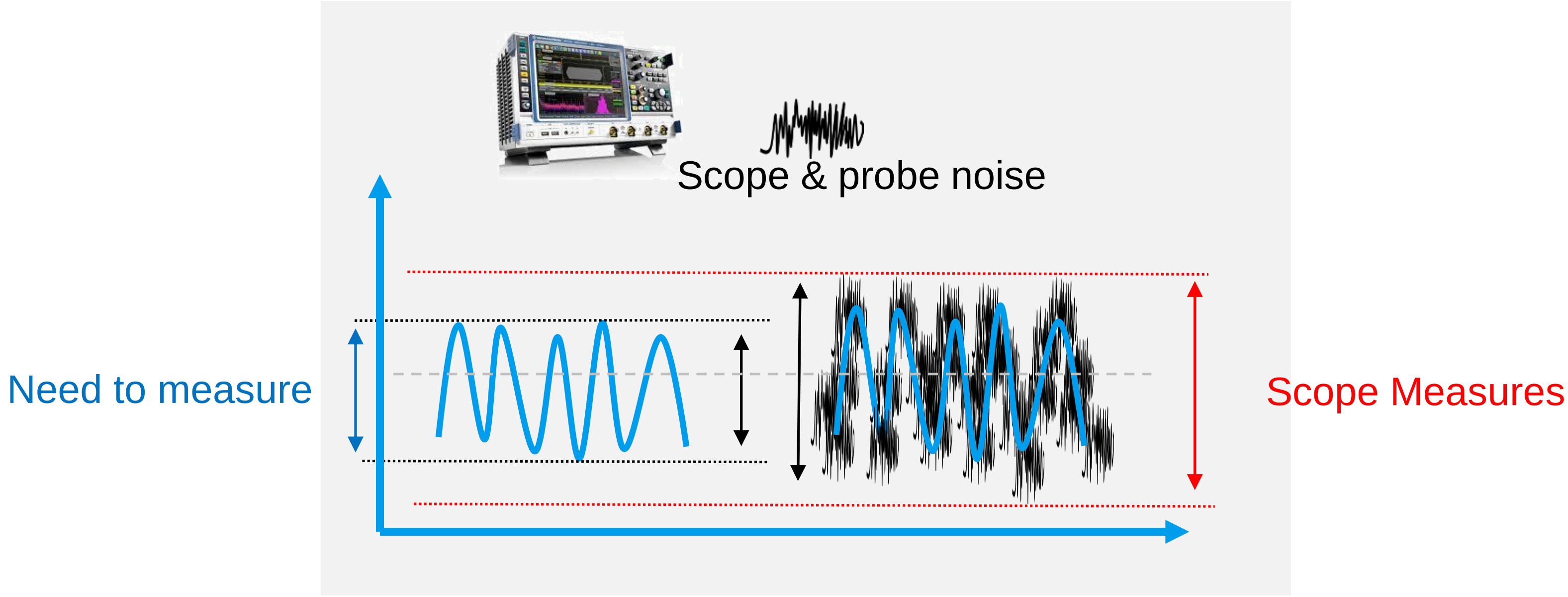
Lower rail voltages and smaller tolerances



Examples

Rail Value	Tolerance	Need to measure
3.3 V	2%	66 mV_{pp}
1.8 V	3 %	30 mV_{pp}
1.2 V	2.5 %	30 mV_{pp}
1 V	3 %	30 mV_{pp}

Several Factors Make It Difficult to Measure Small Signals

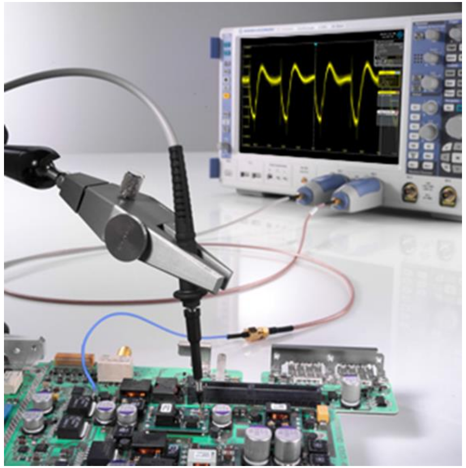


RT-ZPR20 Power Rail Probe

- Designed uniquely for measuring small perturbations on power rails
- Active, single-ended probe
- Low noise with 1:1 attenuation
- Best in class offset compensation capability

Key Specifications	
Attenuation	**1:1**
Probe BW	**2 GHz(*)**
Browser BW	350 MHz
Dynamic Range	±850 mV
Offset Range	**> ±60 V**
Noise Scope (RTO) standalone Scope + Probe Noise (at 1 GHz, 1mV/div)	 107 µV AC_{rms} **120 µV AC_{rms}**
Input Resistance	**50 kΩ** @ DC
R&S ProbeMeter	**Integrated**
Coupling	DC or AC

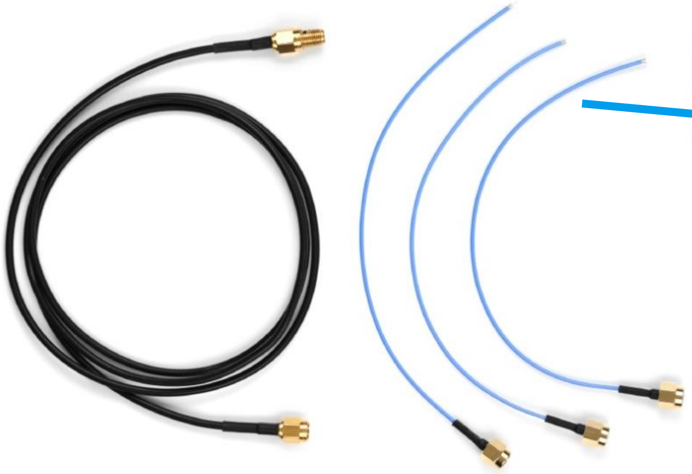
(*) 2.4 GHz band visible due to slow frequency roll-off



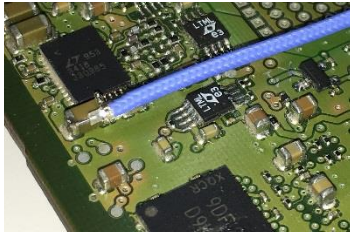
RT-ZPR20 Power Rail Probe

Active probe head, main cable and solder-in cables

Direct connect to SMA



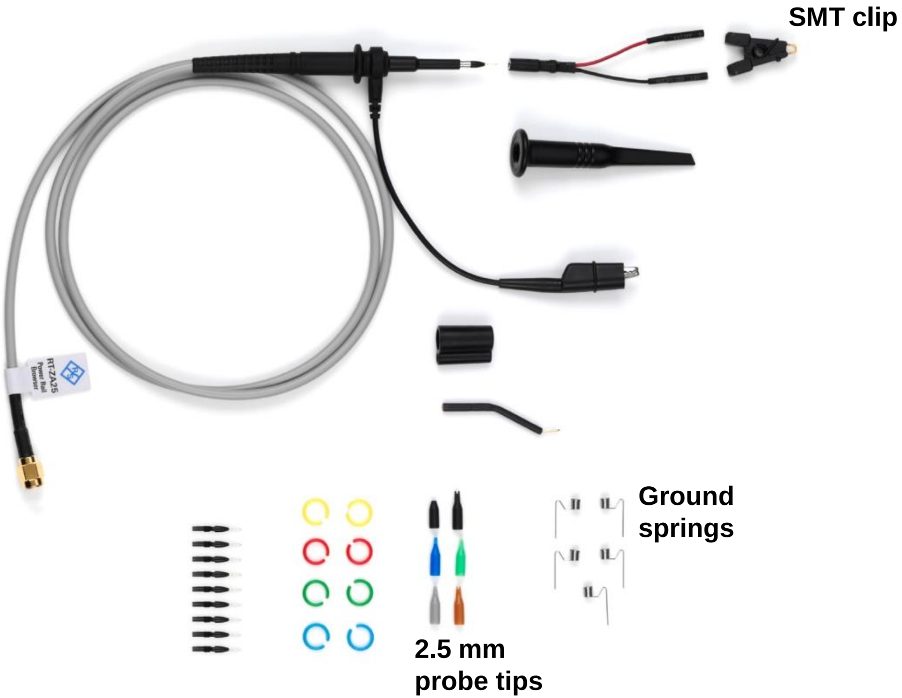
50 Ω SMA coaxial solder-in (2.5 GHz BW)



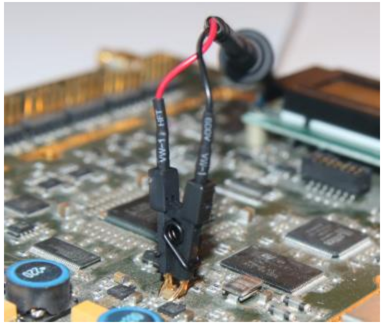
SMA to 2-pin Socket
(male or female options)
ZBX00SAMS-P (reference sell)
http://www.zebax.com/index_files/page1044.htm

ZPR20 Power Rail Probe Browser (included standard)

350 MHz BW, 1:1 active probe, uses passive probe accessories



Ground spring



SMT clip

RTO/RTE Oscilloscopes + Power Rail Probe

V_{pp} with statistics

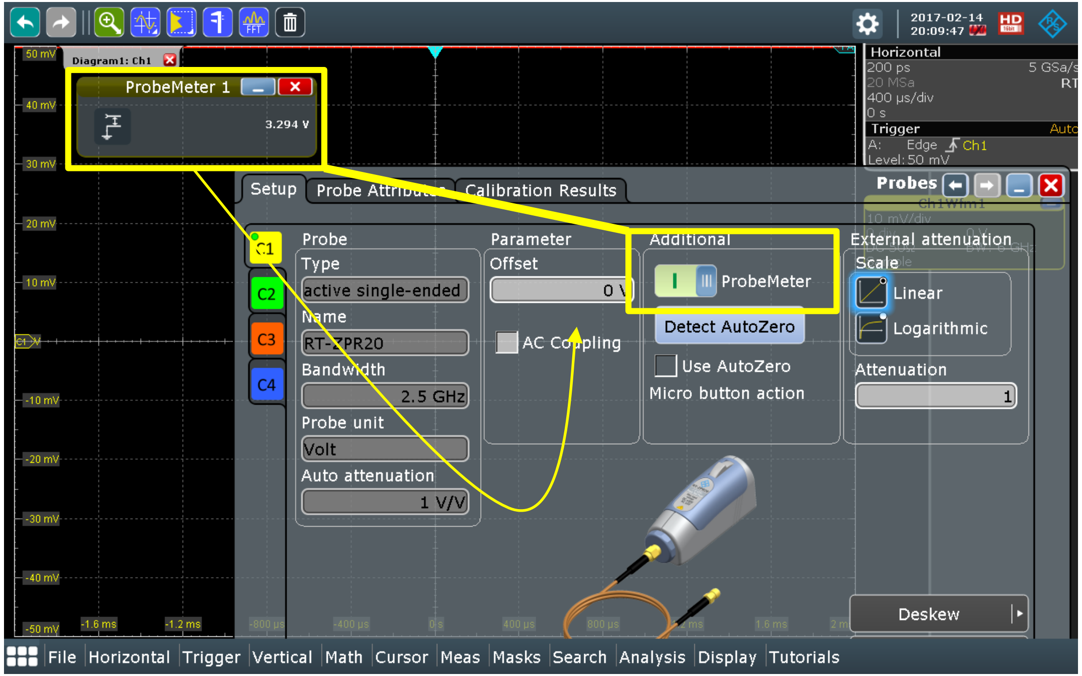
Built in R&S 16-bit ProbeMeter shows DC voltage

High BW shows coupled sources

ZPR20 ProbeMeter

Benefits

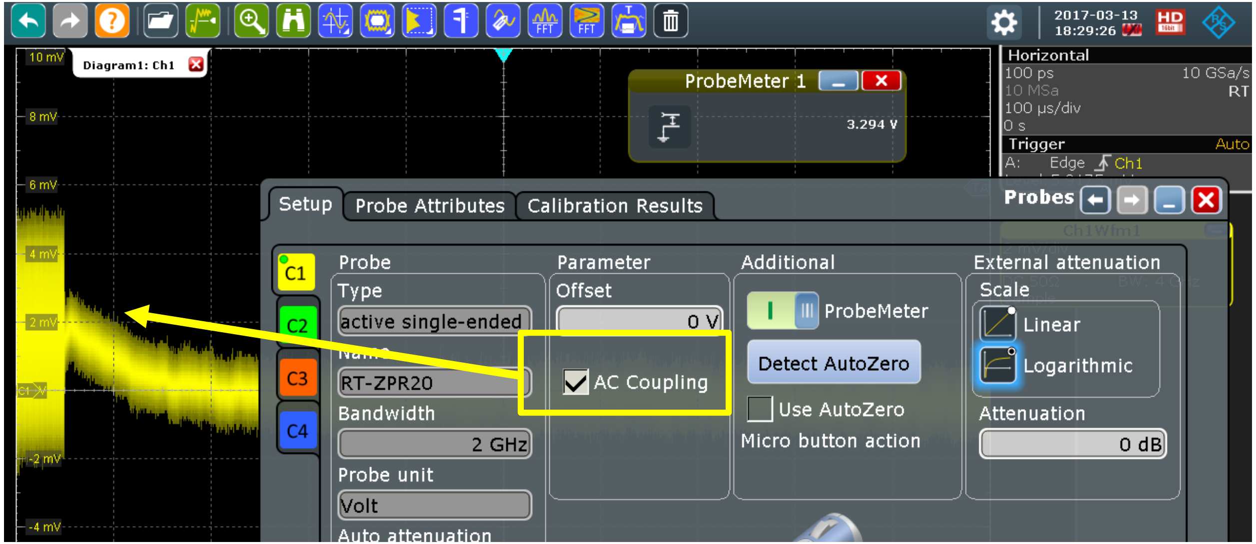
- Shows DC value even if signal if off screen
- Quick way to determine needed offset



ZPR20 AC Coupling

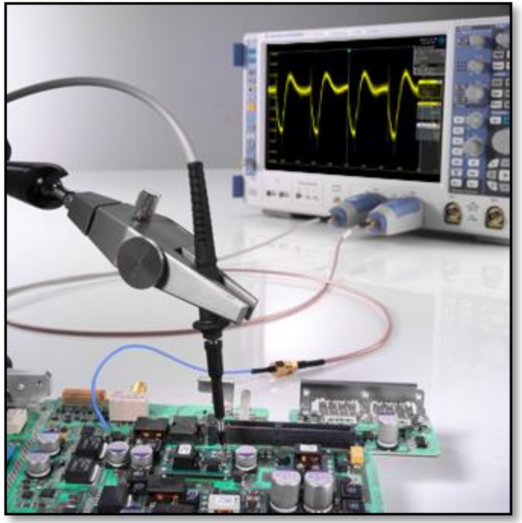
Benefits

- Quickly move from power rail to power rail to measure noise/ripple without having to adjust DC offset with each one.



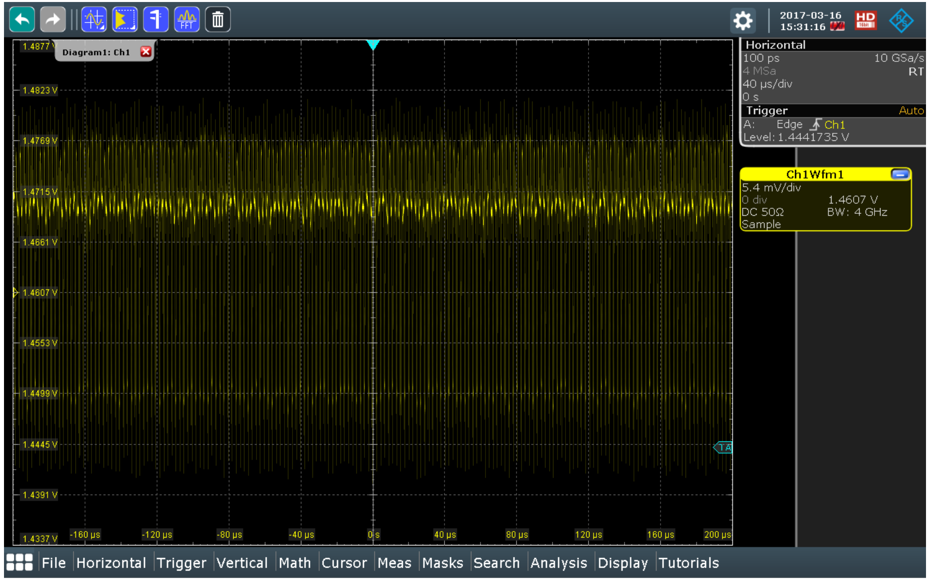
Top Concerns for Power Integrity Measurements

1. Waveform Visibility
2. Measurement accuracy
3. Frequency domain evaluation of coupling/switching
4. Time required to find worst-case violations

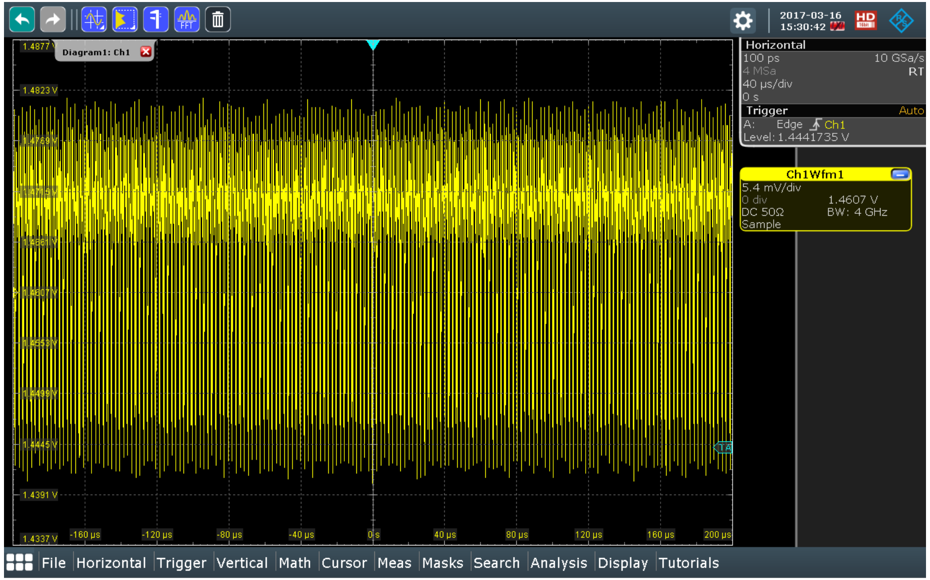


Waveform Intensity

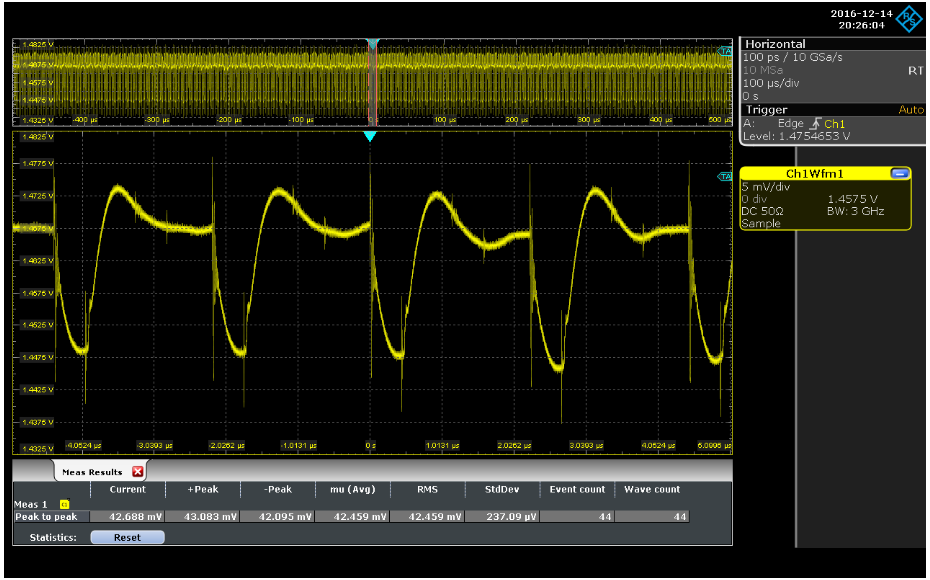
Default – 50%



Adjusted to 90%



Infinite Persistence



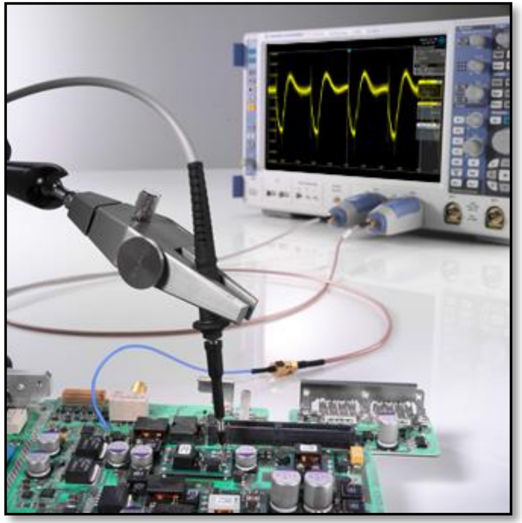
Color Grading

Benefits:

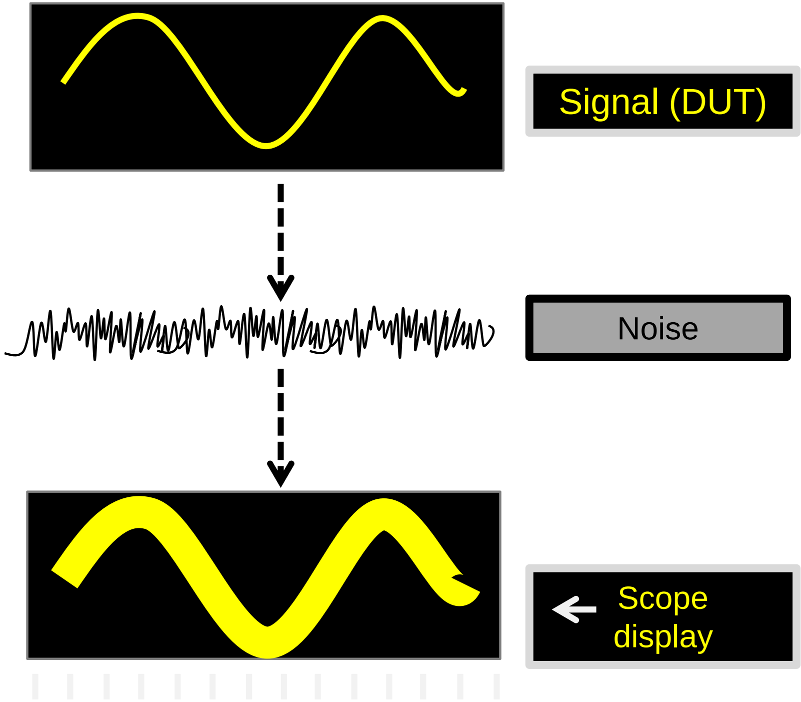
- More easily identify pixels that are hit less frequently.
- See how often anomalies occur

Top Concerns for Power Integrity Measurements

1. Waveform Visibility
2. Measurement accuracy
   - Choose a scope with low noise
   - Use the most sensitive vertical setting
   - Limit BW to what is needed
   - 1 MΩ vs 50Ω path?
   - Choose the right probe (attenuation, BW, and connection)
   - Achieve sufficient offset
3. Frequency domain evaluation of coupling/switching
4. Time required to find worst-case violations



Noise Limits Power Rail V_{pp} Measurement Accuracy



Consequences

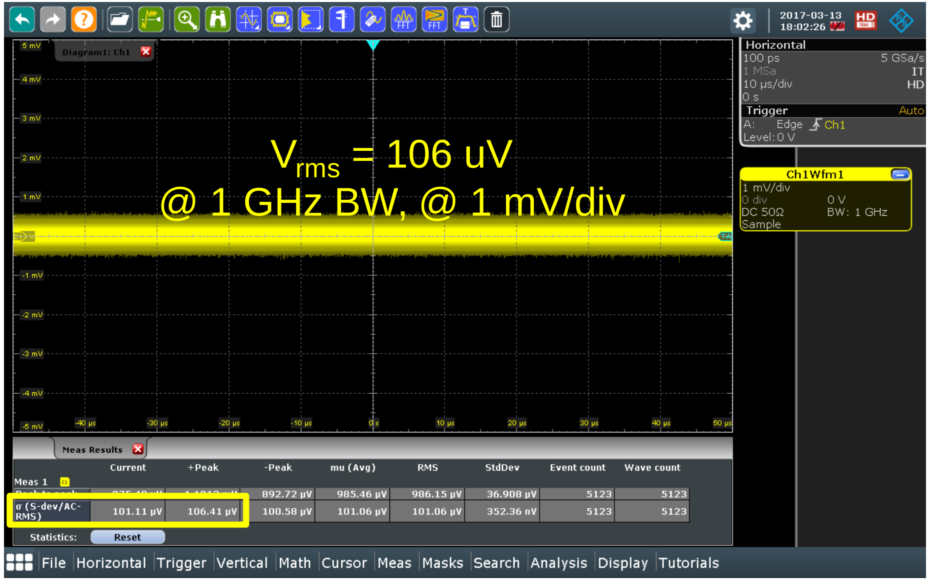
Large measurement deviation

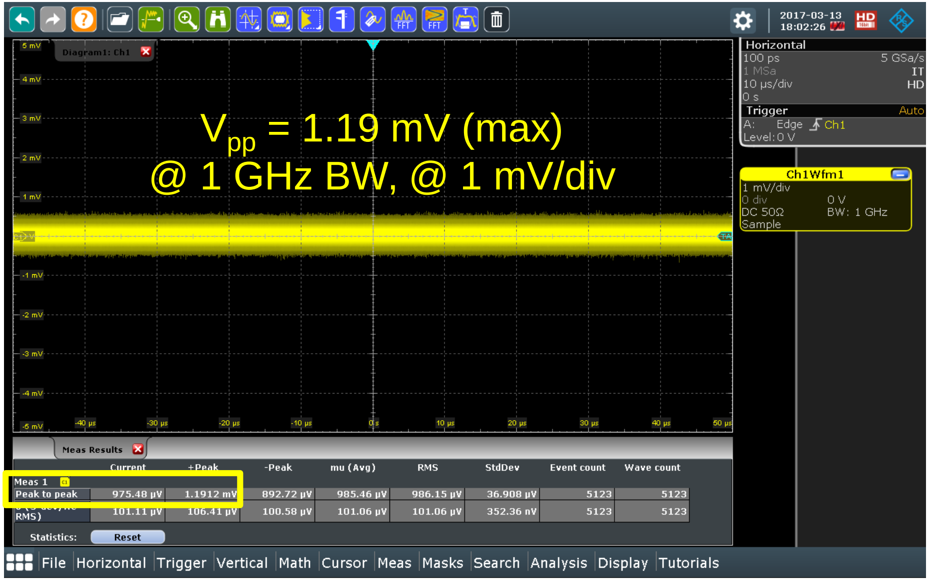
Measured V_{pp} >> Actual V_{pp}

Can mask/hide anomalies

50Ω Check at 1 mV/div

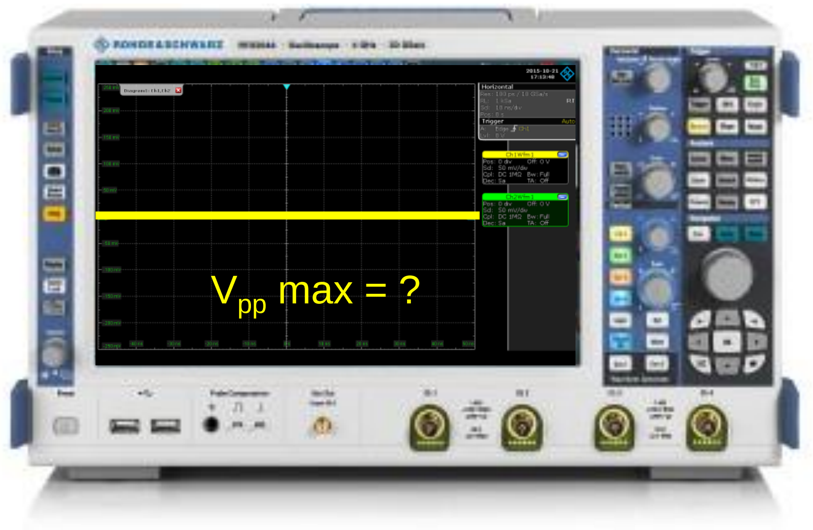
Scope vendors characterize V_{rms} in datasheets, but not V_{pp}





R&S RTO2000 Series

Characterizing Your Scope's V_{pp} Noise in 5 Minutes

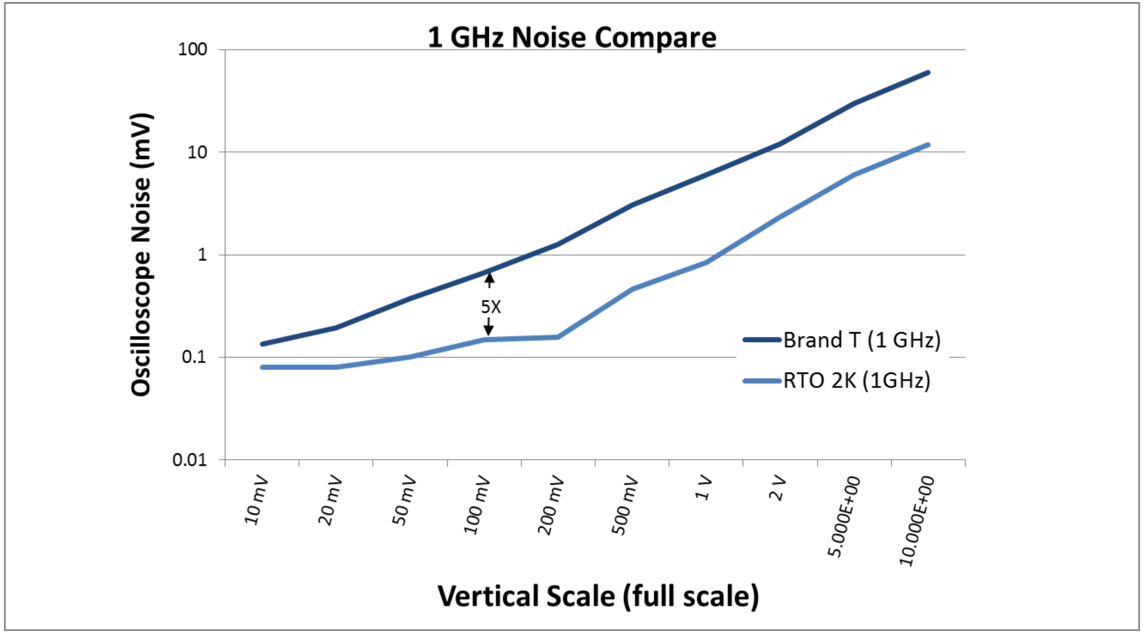


1. Disconnect all inputs
2. Set sample rate (e.g.10 Gsa/s), memory depth, (e.g.1 Mpts), path, and BW to mirror your requirements
3. Turn on Vpp measurement with stats for channel 1
4. Adjust vertical setting to cover the smallest vertical setting you will use
5. Record V_{pp} value
6. Repeat for all other vertical scales that you may use.
7. Repeat for all channels that may be used (will have variation from channel to channel)

(Can perform with probe attached.)

Choose a Scope That Has Low Noise

Comparison Between Two Oscilloscopes with Equivalent Bandwidth



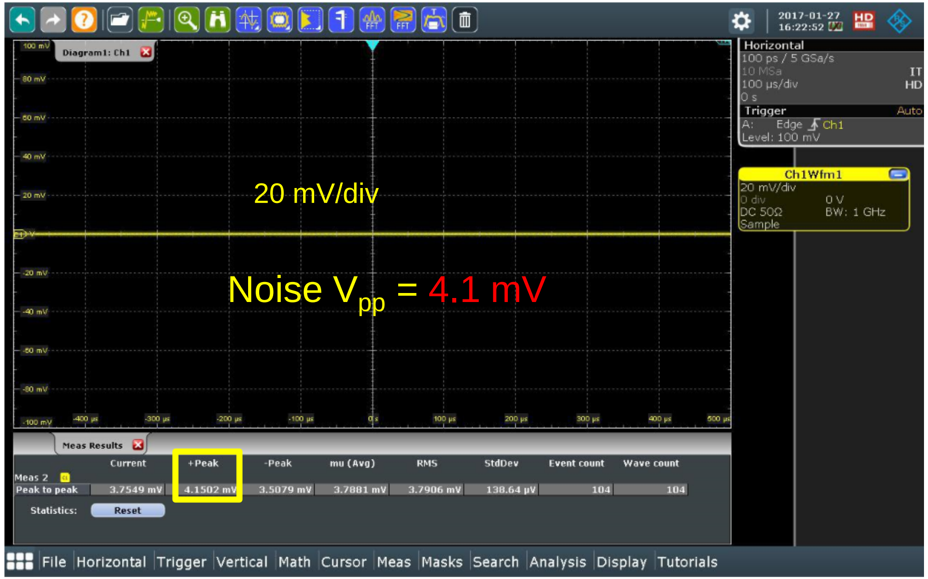
Noise unique to specific scope families, and BW-dependent

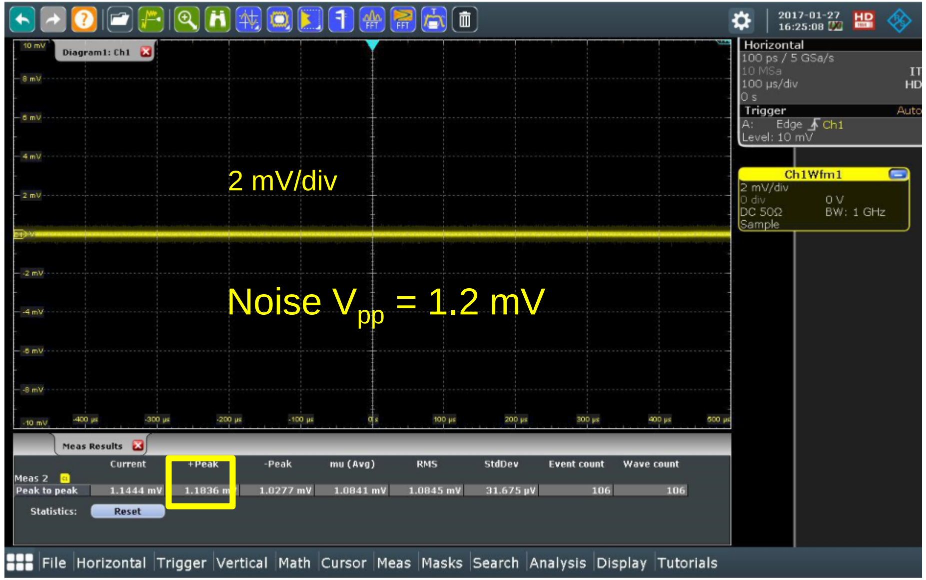
Scope manufacturers characterize Vrms, not Vpp

Use Most Sensitive Vertical Setting Possible

50Ω Input: No inputs connected

All other settings are identical

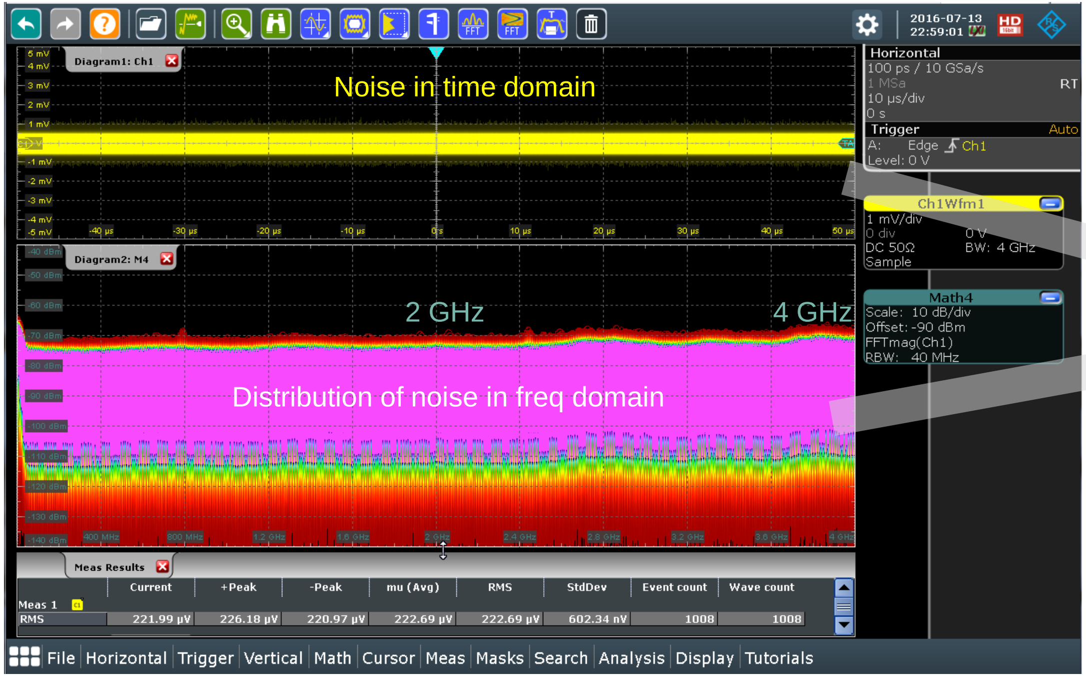




Use the smallest V/div setting to get the most accurate measurement (lowest noise)

Noise Compare: Time Domain vs Spectral Content

No inputs connected



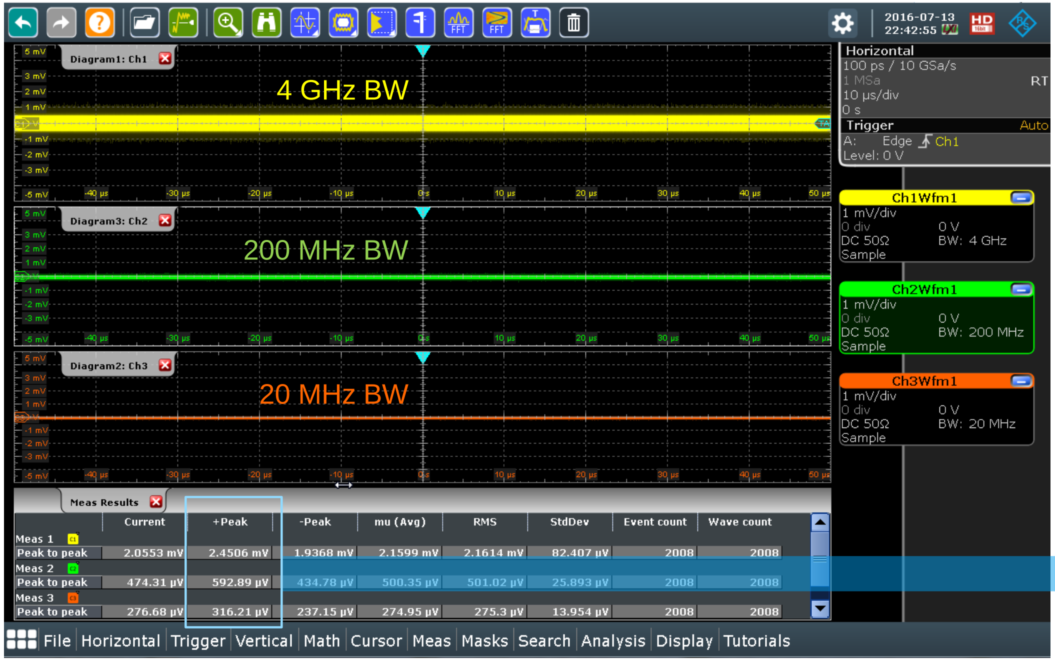
Noise in time domain

=

$\int$ freq domain form 0 to BW

Reduce Noise with BWL Filters

50 Ω path, No inputs connected



All other settings are identical

4 GHz	Vpp = 2.54 mV
200 MHz	Vpp = 0.592 mV
20 MHz	Vpp = 0.316 uV

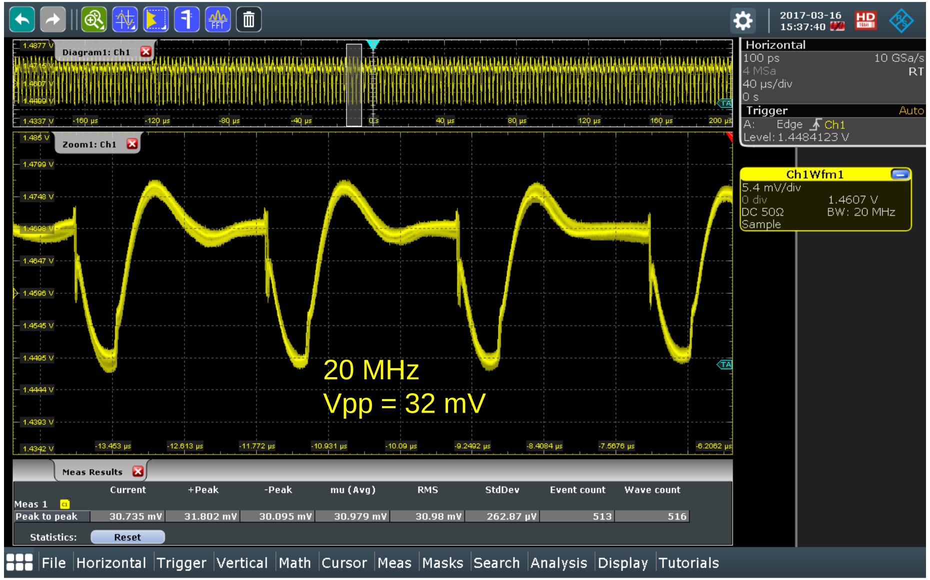
Highest noise

Lowest noise

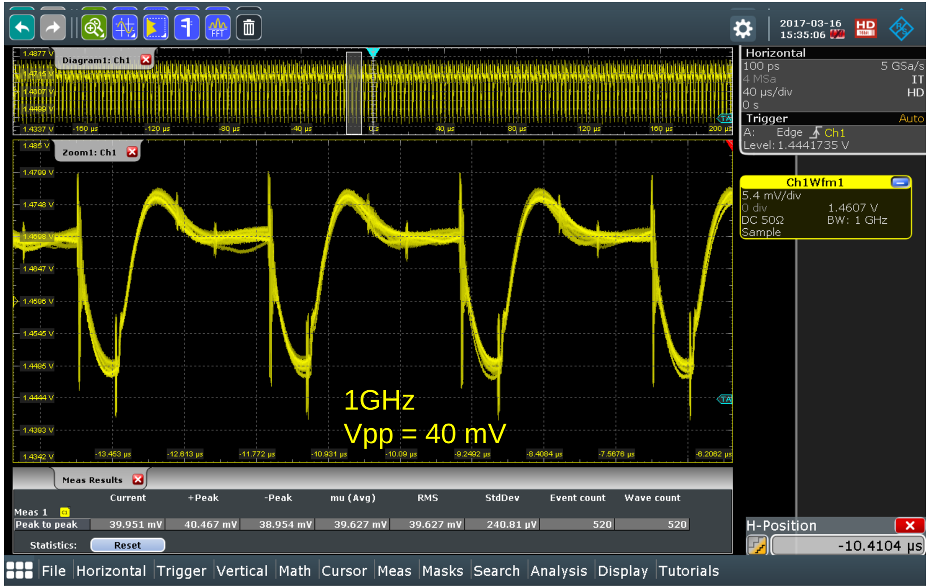
BWL for noise reduction. Ensure signal harmonics you care about are in the BWL filter you set.

How Much BW Do You Need?

20 MHz



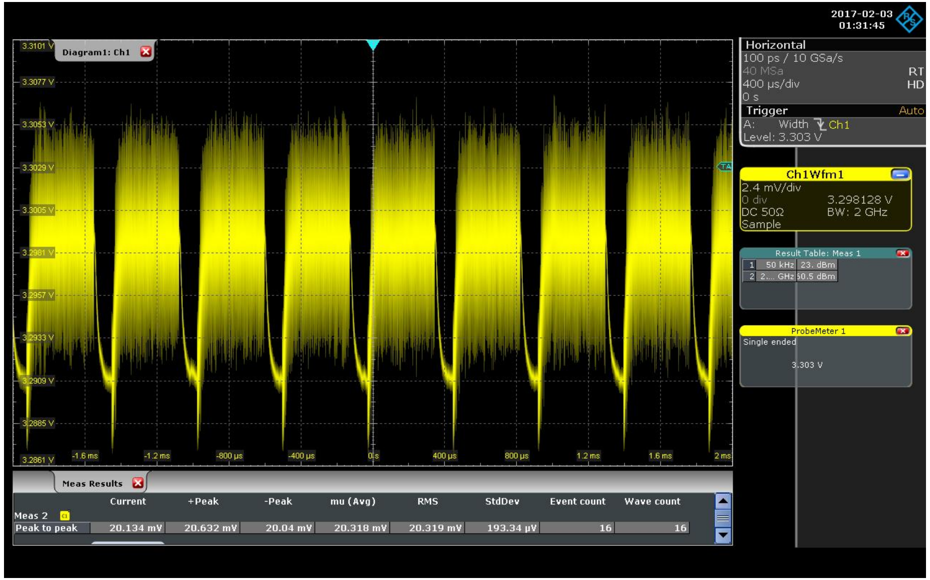
1 GHz



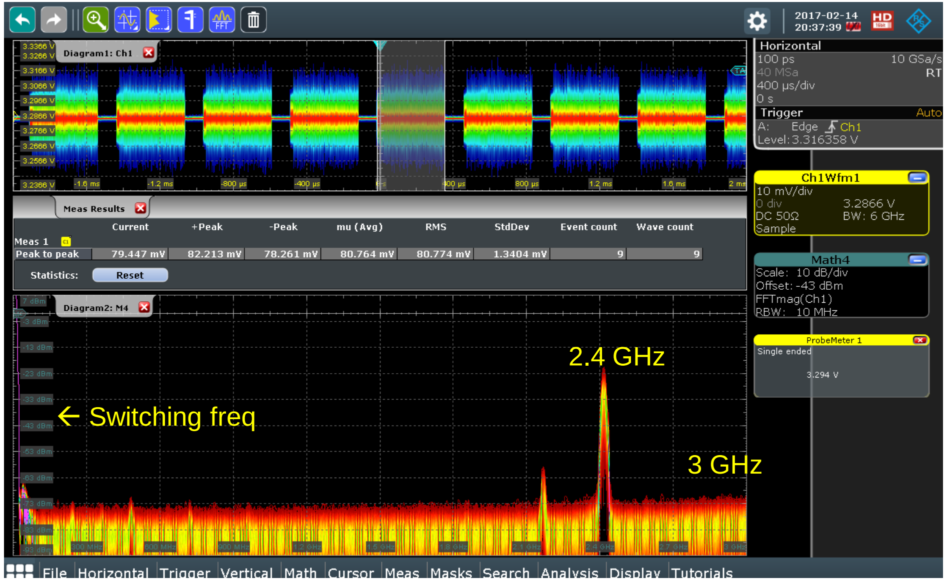
How Much Bandwidth Do You Need?

It depends.

How much is needed here?

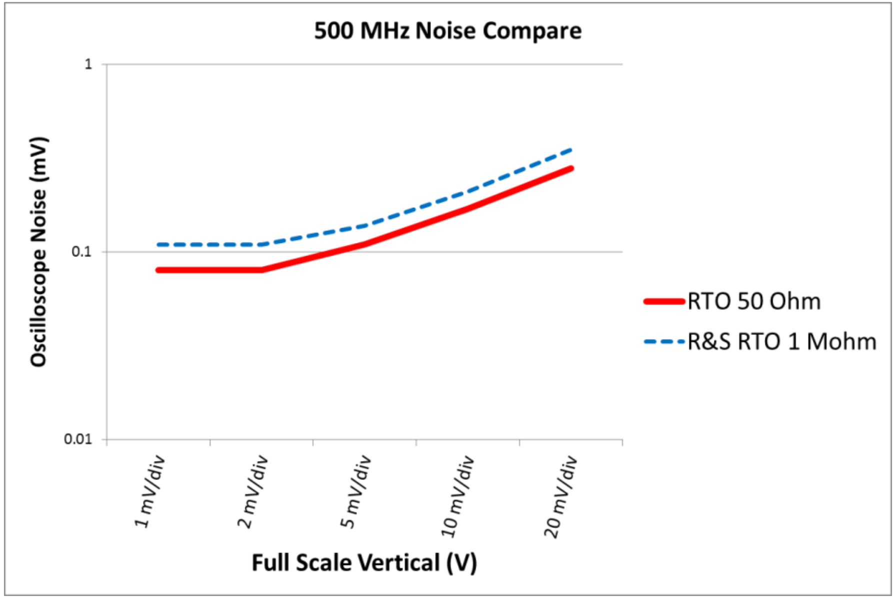


How much is needed here?



Choice of using 50Ω vs 1MΩ

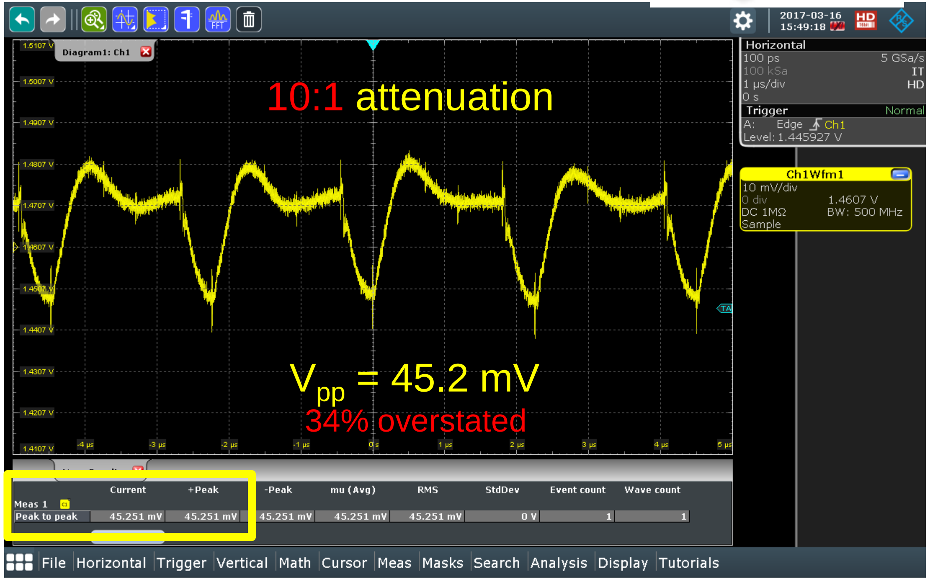
- 1MΩ path provides better loading…but only has 500 MHz BW, and typically more noise.
- Best approach is to use 50Ω (quieter path) with a specialized probe that provides better loading.



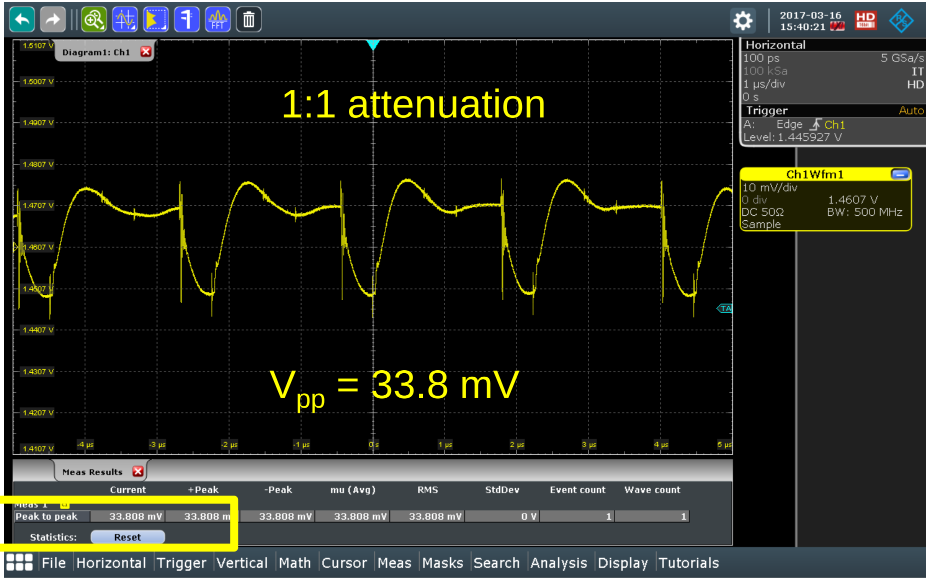
Choose the right probe

Measurement Accuracy: Noise Due to Probe Attenuation Ratio

10:1 (10 mV/div)

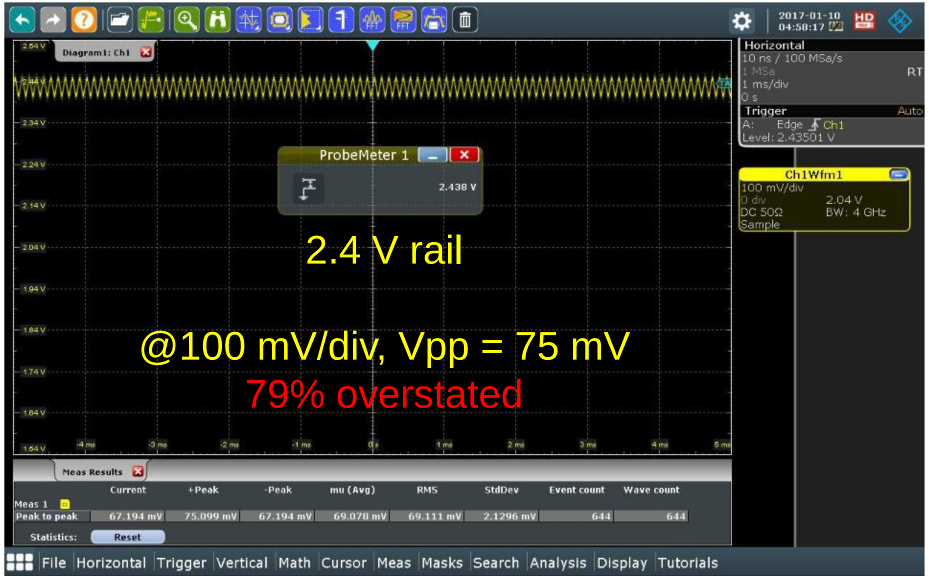


1:1 (10 mV/div)

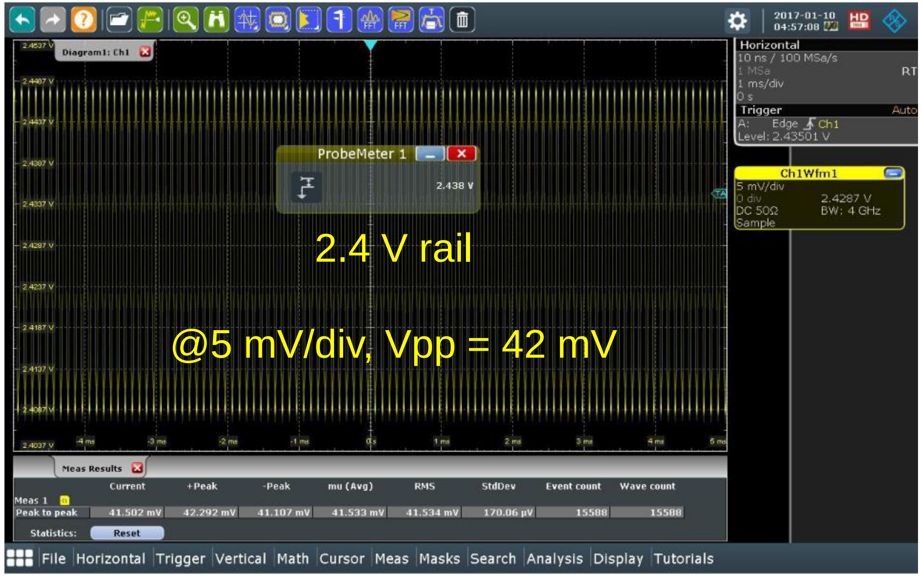


Measurement Accuracy: Using Most Sensitive Vertical Setting

Using max built-in scope offset

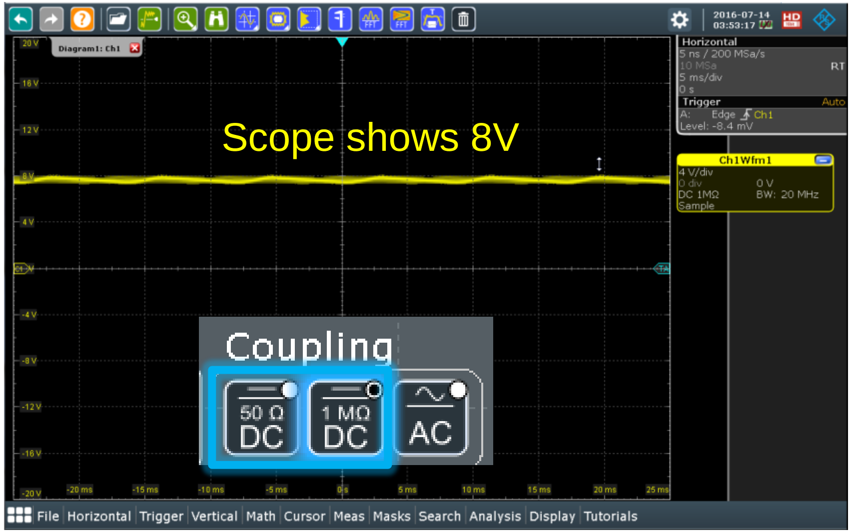


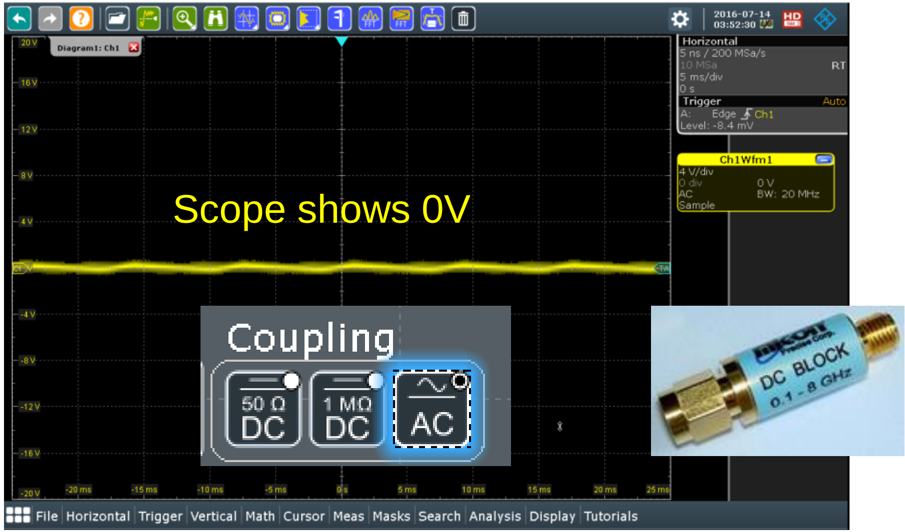
Using built-in probe offset



Challenges with Insufficient Scope Offset

AC coupling mode and blocking caps eliminate ability to see DC value





Can't zoom in (1V offset on RTO @ 20 mV/div) →

Can bring to center screen and zoom in

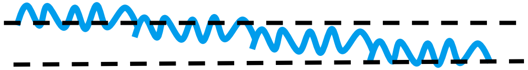
User can't tell absolute vertical value

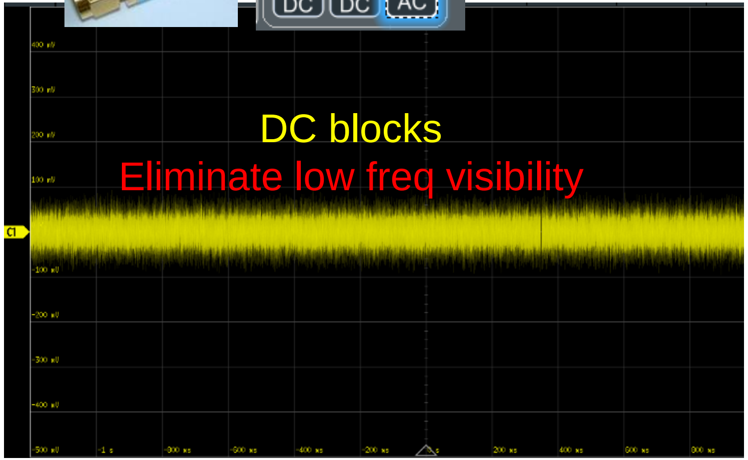
User can't see DC offset issues

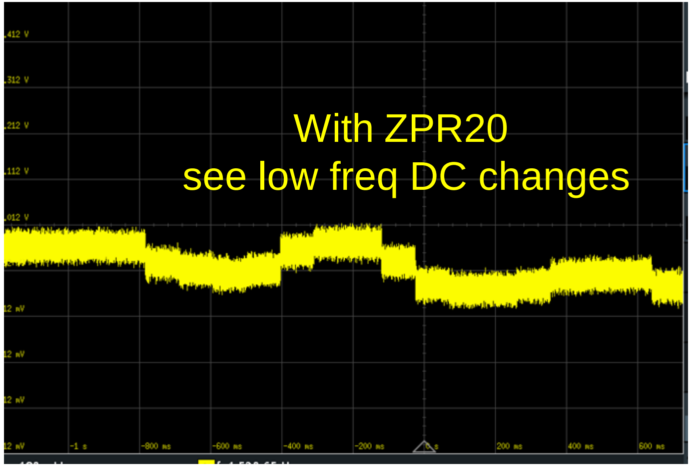
Challenges with Insufficient Scope Offset

AC coupling mode and blocking caps eliminate ability to see DC changes

DC Drift

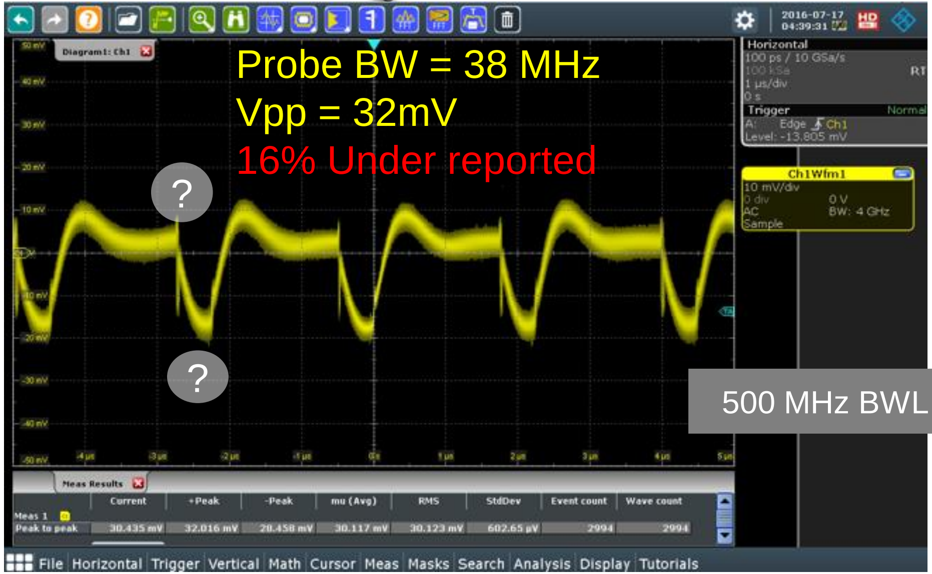


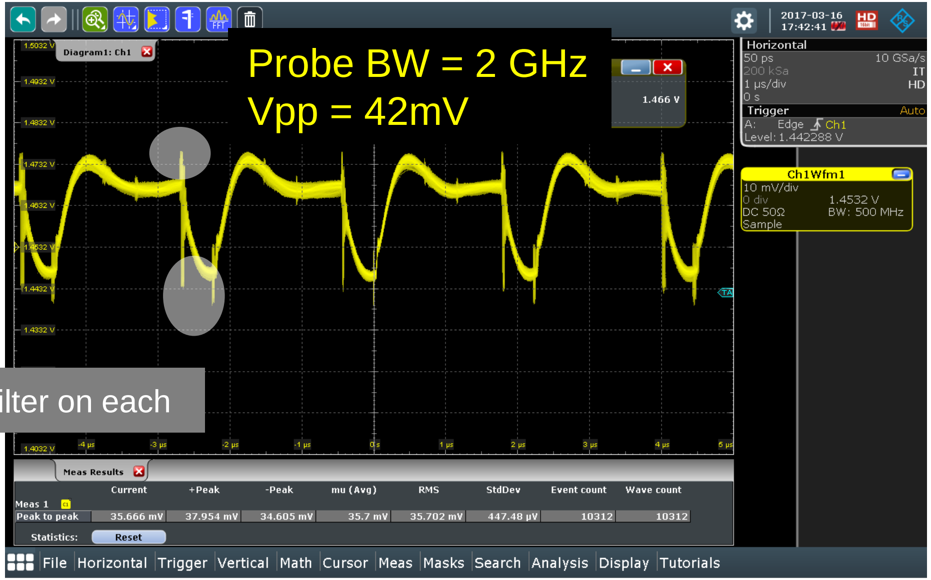




Measurement Accuracy: High BW Needed for High Frequency Transients

Both 1:1 Probes





500 MHz BWL filter on each

1:1 ZP1X passive 38 MHz BW

1:1 ZPR20 active 2 GHz BW
Captures high-frequency transients

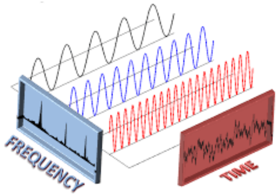
Making Most Accurate Power Rail Measurements

1. Measurement accuracy
2. Frequency domain evaluation of coupling/switching
3. Time required to find worst-case violations

ZPR20 + RTO:

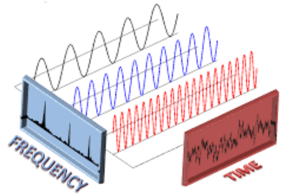
2 GHz BW to capture high-frequency transients (2.4 GHz typical 3dB point)
HW-accelerated FFT
Color graded FFTs

See Switching



Switching (low freq FFT)

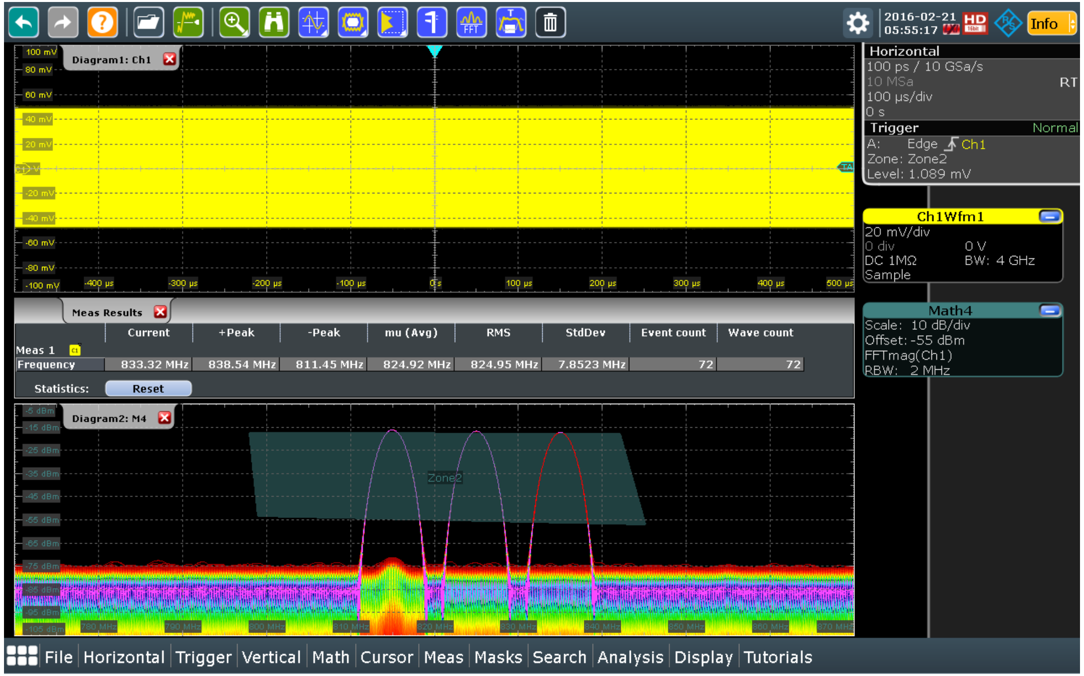
Finding Coupled Signals



EMI Coupling

Zone Triggering in Frequency Domain

- Unique to R&S RTO
- Trigger if scope finds power violations at specified frequencies



Making Most Accurate Power Rail Measurements

1. Measurement accuracy
2. Frequency domain evaluation of coupling/switching
3. Time required to find worst-case violations

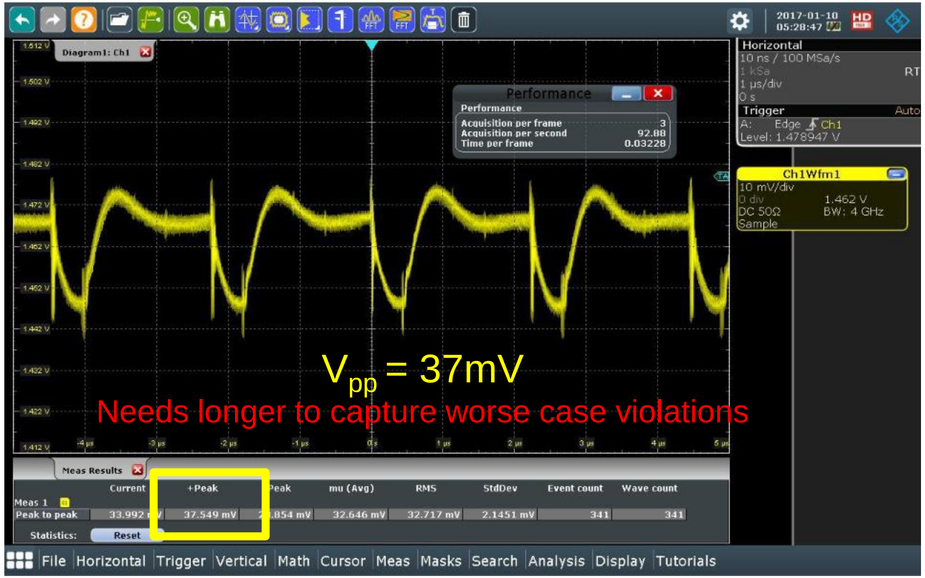
RT-ZPR20 + RTO:

Up to 1 Mio wfms/s (1000X faster than other scopes in class)

Measurements with statistics

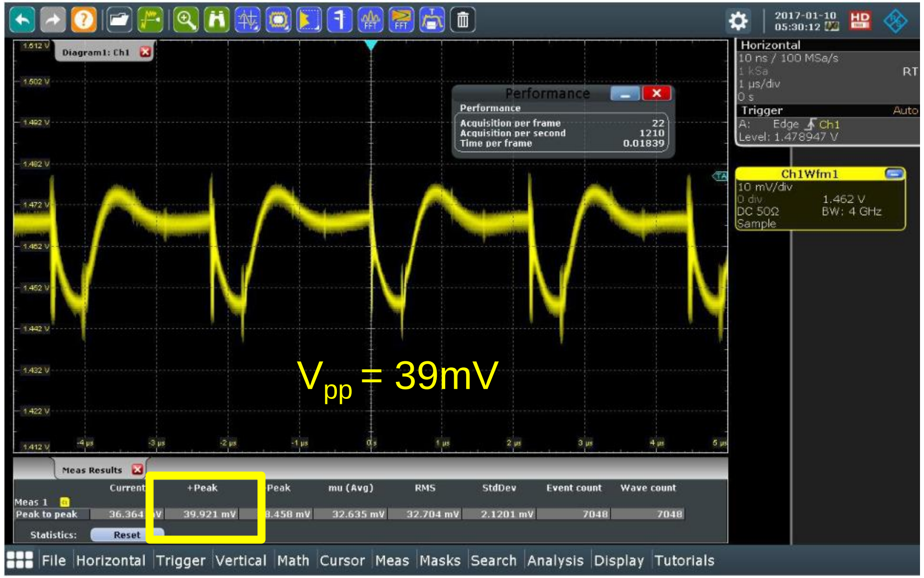
Find Worse-case Violations Faster

Example: 5 Seconds of Measurements



Emulating competitive update rate of 100 wf/s

< 500 Vpp measurements in 5 seconds



>5000 Vpp measurements in 5 seconds

Fast Update Rate (up to 1 Mwfs/s)

Fast update rate shows modulated signal on power rail.

Difficult to see on scopes with slower update rate.

Gives an indication that a freq domain view is needed

ZPR20 Recommended Configuration

- RTE 1 GHz + ZPR20 Power Rail
  - Economic solution for many power integrity problems

- RTO 4 GHz + ZPR20 Power Rail
  - Top end solution, covers EMI coupling > 2 GHz